Model study of log feeding technology at the dam of Ertan Hydropower Station in China

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Abstract The log float technology from timber depot at the reservoir to log feeding rolls was studied by model tests. The model test was taken with the rule of gravitation similitude and ratio of 1:10. Main parameters, like the amount of tug boats, hydro-accelerators and the structure of feeding rolls, were determined. The more suitable float process is put forward and the reliable basis for the design is supplied.

Key words: Model test. Logs, Feeding technology, Tug boat

Introduction

Ertan hydropower station is situated in Sichuan Province. It is 30 km from the exit of Yalong River. It is a big key project for water control. Its main purpose is to generate electricity and crossing the floated logs over dam must be dealt with as well. The height of dam is 240 m. It consists of four systems (dam, flood-discharge tunnel, workshop system, and log passing tunnel). The electricity generation capacity is 3.3 million kw. The electric energy production is 17 billion kilowatts a year. The reservoir capacity is 5.8 billion m^3. The normal water level is 1 200 m in elevation. The minimum water level is 1 155 m. The alteration range of water level is 45 m.

The volume of logs crossing dam a year is 1.1 million m^3. Crossing the logs over dam is done by three combine conveyers. The engineering installations include log feeding facilities, up-slope rollers, belt conveyers in tunnel and steel channel for exit.

Operation period: 90 d (July-Sept.), 12 h a day

The characters of logs:

Length:

L(m)	<2	2-2.8	3-3.8	4-4.8	5-5.8	6-6.8	7-7.8	>8
%	2.98	18.91	18.55	16.9	16.3	24.8	1.49	0.07

Diameter:

D (cm)	<20	20-28	30-38	>40
%	14.7	42.75	28-3	14.25

The max. diameter of logs is 1 m. The longest log is 8 m. The average density of log is 800 kg/m^3.

The model test was used mainly to solve the log feed technology from water depot to log feeding facilities to satisfy the log volume demand for crossing dam and to confirm some technical data. The specific demands are as follows:

(a) Short distance (about 500 m) transportation from water depot to hydro-accelerating section in feed division,

(b) Specification of technical data of hydro-accelerators

(c) Specification of technical data of feeding rolls.

Study method

The study was carried out as by model test. The model tests were designed according to the Froude law (Yang 1997; Zuo 1984). The model scale was 1:10.

Test and research

Short distance transportation test

The average distance from water storage to feed rolls was 500 m. In this area, the current velocity was almost equal to zero, At first, we carried out log-pulling tests by tug boats with log-pulling devices (Qi 1984). We fixed log-pulling device at the front of a operation ship. The operation sequence of tug boat is as follow:

Enter storage area → Put down log-pull device → Pull logs to hydro-accelerating section → Go back and pull up device → Go to water depot → Next turn.

The model tug boat's specification: length 1.7 m, width 0.3 m, draught 0.04 m

The velocity range of tug boat

V_m (model) m/s	0.2	0.25	0.3	0.35	0.4
V_p (prototype) m/s	0.63	0.72	0.95	1.11	1.26

The relationship between the velocity and log-pulling volume

V_m m/s	0.2	0.25	0.3	0.35	0.4
V(volume) m^3	3.98	76.15	22.71	13.59	12.56*

*(changed to prototype)

We carried out the width and draught tests of tug boat. The results show that there is negative effect to log-pull volume when the draught changes when the draught of log-pull device is more than that of logs. When the width is increased the volume is increased as well. But the volume of unit length is almost same. The width of log-pull device is effected by the width

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and operating characters of a tug boat and the operation area of water.

The volume of log-pull is stochastic in a certain velocity. When V_m is 0.6 m/s (V_p =1.9 m/s), logs will float from the bottom of log-pull device.

Because log-pull volume is small and stochastic each time, more ships will be needed in order to satisfy the volume of crossing dam. It will increase the investment. So we need choose another way of small bag raft tugged by two tug boats for testing.

The operation procedure:

One tug boat enters storage and forms a small bag raft → move forward → unload → move back → next turn.

We carried out several tests with volume 100, 200, 300 and 400 m^3. The results show that the small bag raft dragged by two ships has the character of steady feeding. With hydro-accelerating tests, the volume of 300 m^3 is suitable. The velocity is under 1.8 m/s. If velocity is more than 1.8 m/s the logs will float out the bag.

The bag raft velocity is determined to be 0.6 m/s.

The time for one cycle:

Tug boat with log-pulling device:18 min (the average volume is 30 m^3 per boat)

Small bag raft: 28 min (the volume is 300 m^3 per turn)

The number of tug boats: log-pull: 17; bag raft: 6.

We choose the small bag raft dragged by two ships as the way of short distance transportation in order to minimize investment.

Tests of hydro-accelerators

The purpose of hydro-accelerators is to make logs enter the log feeding facilities at needed velocity and direction when logs are out of control of two ships. With the prototype of a ЛР-49 hydro-accelerator (made in Russia), the model test was carried out. In model tests, water is supplied by a pump and spurted by a pipe. By adjusting the flow of a pipe, to ensure the resemblance of the current velocity in different distances.

The relation between the current velocity in model axis and distances of different flows is as follows.

V_m (cm/s)

Distance (m)	3	4	5	6	7
Flow (16 m^3/h)	26.38	22.79	17.75	13.77	12.26
Flow (19 m^3/h)	35.81	28.05	20.38	15.99	13.73

Annotation: the depth of the pipe is 4.5 cm under water (model)

Hydro-accelerators are located in booms in shape of "八".There are two accelerators in each side. The distances from accelerators to the top of floating tank are 3.0 m and 4.5 m individually. When logs pass different channels, the angles of pipes are adjusted accordingly to satisfy the passing demand.

Table 1 shows the relations among the capacity, flow and angles.

Table 1. The relations among capacity, flow and angles.

NO.	Pump data Flow /$m^3 \cdot h^{-1}$ Q_1	Q_2	Q_3	Q_4	Angle (°) α_1	α_2	α_3	α_4	Channel ①	②	③	Passing volume /m^3	Time /min	Passing volume (prototype) /$m^3 \cdot h^{-1}$
1	16	16	19	19	5	35	7	30			*	0.6	9.63	1 182
2	16	16	19	19	5	35	7	30			*	0.6	11.13	1 023
3	16	16	19	19	25	25	20	20		*		0.6	13.50	843
4	16	16	19	19	20	20	25	25		*		0.6	12.22	9 321
5	16	16	19	19	20	20	25	25		*		0.6	14.95	761
6	16	16	19	19	35	5	30	7	*			0.6	13.34	853
7	16	16	19	19	5	5	15	15	*		*	0.6	12.95	879
8	16	16	19	19	5	5	15	15	*		*	0.6	11.80	965
9	16	16	19	19	5	5	15	15	*		*	0.6	13.70	831
10	16	16	19	19	5	20	7	15		*	*	0.6	9.88	1 152
11	16	16	19	19	5	25	7	25		*	*	0.6	8.23	1 383
12	16	16	19	19	5	7	25	25		*	*	0.6	11.00	1 035
13	16	16	19	19	5	25	7	25		*	*	0.6	6.55	1 738
14	16	16	19	19	7	7	25	25	*	*	*	0.6	8.73	1 304
15	16	16	19	19	7	7	15	15	*	*	*	0.6	10.62	1 072
16	16	16	19	19	5	5	15	15	*	*	*	0.6	8.53	1 334
17	16	16	19	19	5	5	15	15	*	*	*	0.6	7.63	1 492
18	16	16	19	19	5	5	15	15	*	*	*	0.6	12.92	881
19	16	16	19	19	5	5	15	15	*	*	*	0.6	9.75	1 168
20	16	16	19	19	5	5	15	15	*	*	*	0.6	8.50	1 339
21	16	16	19	19	5	5	15	15	*	*	*	0.6	6.00	1 897

Accelerating effect

According to the test demand, we carried out tests of configurations for single, double and three channels.

Single channel

The accelerating effect is obvious to any single channel. We can choose different spray angles to ensure the coincide between the channel center and influence of accelerators in two sides. Under the condition of relative even feed, logs can pass the channel smoothly and the capacity can reach 500 m^3/h.

Double channels

When two neighboring channels pass logs, the influence of hydro-accelerators is just in the axis of two channels (the top of floating tank). Logs can enter one channel randomly. When logs bump the top of floating tank, their velocity will decrease and form a log-jam. So two rolls are set up on the top of floating tank. By continuous moveness of rolls, the log-jam is removed. By changing the rotation direction of rolls, the volume of two neighboring channels can be balanced. The passing capacity of two channels is more than 1 000 m^3/s.

Three channels

In this case, the angles of two front hydro-accelerators should be small, helping logs to enter two channels in two sides. The angles of two backward hydro-accelerators should be a little larger to ensure certain current velocity in middle channel. The two rolls must be settled on the top of floating tanks. By continuous rotation of rolls, the log-jam will be eliminated. We can balance the passing volume by changing the rotation direction of rolls. The passing capacity is more than 1 500 m^3/h.

There should be two tug boats with pulling device in front of hydro-accelerators. When logs can not enter the section of hydro-accelerators, a tug boat with pulling device would push logs to enter the section.

Log feed facility

According to test demands, the roll length is 7 m (model 0.7m) and the slope-angle of rolls is 15-17 degree. There are ten steel spiles around a log feed roll.

At first, we carried on straight-pull tests of logs that enter the first roll with certain angles. When roll velocities are increased one by one, logs will rotate certain angles and be pulled straight. We carried on three kinds of tests with the velocity ratio of 1:1.07, 1:1.08, 1:1.09 between neighboring rolls. The effect is obvious to small and short logs. The bigger the ratio of velocity is, the better the effect is. So in order to improve the effect of log-pull, we should adopt relative large ratio of roll velocity.

In tests, we found that when one side of a big log is pushed by the first roll, the other side of the log will drop rapidly. The log gets into a slope state. There's a minus pressure section. The water will flow through this section rapidly and small logs will enter this section. This will form the state of concurrent transportation of two or three logs. When the slope angle is 17 degree the situation is severe. While changing to 15 degree the case is improved and the logs enter slope rolls easily.

Results and conclusions

Through the tests mentioned above, small bag raft dragged by two boats is a better way for short distance transportation in the reservoir of Ertan Hydropower Station. Two tug boats play an additional role in the front section of hydro-accelerators.

By choosing ЛР−49 (made in Russia) as hydro-accelerators and mounting two of them on each side the demand of different channels would be met by changing the angles of pipes. In order to avoid log-jam in front of the top of floating tanks, two rolls should be installed. They can break log-jam and even out the volume on neighboring channels.

The velocity of rolls should increase one by one from the bottom to top in order to pull logs straight. The slope of 15 degree is better than 17 degree for logs up.

Through model tests, the suitable feed technology was put up and appraised by experts in July 1994. Fig.1 describing technological process of feeding logs (see next page).

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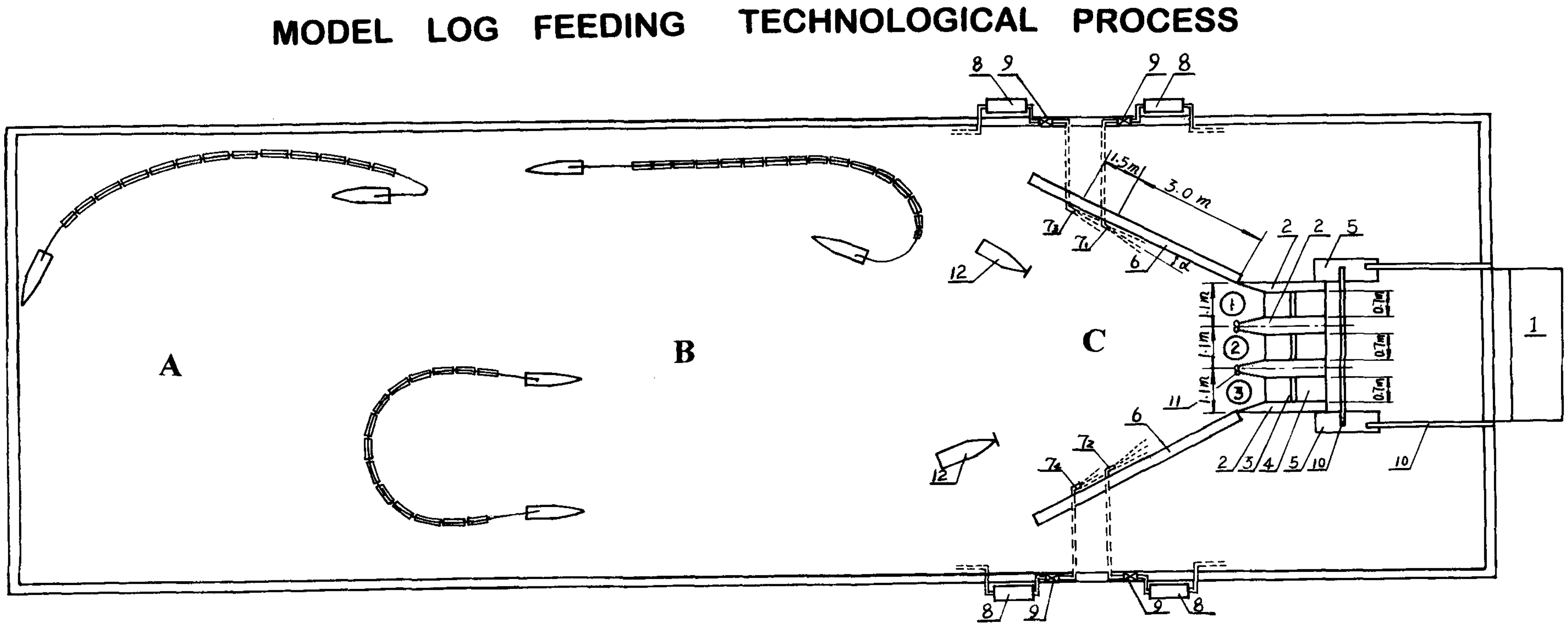

Fig 1. Model log feeding technological process

A--Log depot section; B--Sort distance transportation section; C--Hydro-accelerating section

1. General control room	7. Hydro-accelerators
2. Floating tank	8. Pumps
3. Feeding rolls	9. Flow adjusters
4. Up-slope rolls	10. Bridges for work
5. Block for up-slope rolls	11. Vertical rolls for breaking log jam
6. Floating tank	12. Tug boats